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RESEARCH ARTICLE OPEN ACCESS

Shear and Flexural Behaviour of R.C.C. Beam With Circular Opening Strengthened By CFRP Sheets

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ABSTRACT
This paper explores the behavior of R.C.C. beam with circular opening strengthened by CFRP sheets. In this experimental work five beams were casted, one beam without opening (i.e. solid beam) and one with circular post opening and considered as control beams. The remaining three beams were externally strengthened by Carbon fiber reinforced polymer (CFRP) sheets with different strengthening schemes i.e. around the opening, inside the opening. These beams were simply supported and tested less than two points loading in the loading frame. The behaviors of such beams were studied in terms of load carrying capacity, load-deflection behavior and cracking patterns. From the test results it is concluded that the ultimate load carrying capacity of the R.C.C. beam strengthened with CFRP sheets increased in the range of 13.01% to 55.32%. Among all the strengthening schemes, the strengthening with CFRP around and inside the opening was found very effective in improving the ultimate load carrying capacity of beam.
Keywords: Reinforced concrete beams, Beams with circular opening, CFRP, Strengthening schemes, Ultimateload carrying capacity.

I. INTRODUCTION

In modern building construction openings in beams are used to provide passage for utility ducts and pipes In the construction of multi-storey buildings, many pipes and ducts are necessary to provided for services like water supply, sewage, air-conditioning, electricity, telephone, and computer network. Normally, these pipes and ducts are placed underneath the beam soffit and for aesthetic reasons, are covered by a suspended ceiling, thus creating a *dead space*. Passing these ducts through transverse openings in the floor beams leads to a reduction in the dead space and results in a more compact design and thus inclusion of openings in beams alters the simple beam behavior to a more complex one. [1 and 5].

Strengthening of beams provided with openings depends mainly on whether those openings are pre-planned or post-planned. In the case of pre-planned openings, both the upper and lower chords are designed and reinforced to resist the internal forces that they are subjected to two point loads. The design of such chords depends on the position of opening and the type of loading [1]. A steel reinforcement is provided around the opening edges and extended with enough length beyond the opening corners to resist the stress concentration. Both the reinforcement provided for the upper and lower chords and the steel reinforcement provided around the opening are considered as internal strengthening.

Quite few methods of strengthening the beams with openings, more common ones are strengthening by Carbon Fiber Reinforced Polymer Sheets (CERP Sheets), Glass Fiber Reinforced Polymer Sheets (GFRP Sheets), Aramid Fiber Reinforced Polymer Sheets (AFRP), Steel Plates and Strengthening by steel reinforcement [3, 4, 5 and 2].

In this paper behavior of beams with opening under different types of strengthening process using CFRP Sheets is carried out. Five beams were casted; four beams were with circular post opening provided by using drilling machine. Three beams are strengthened with CFRP sheets and remaining one beam with circular post opening (non-strengthened) for comparison. These beams are tested under two point loading in the loading frame, the ultimate failure load of the beam and deflection have been recorded and results were compared with the control beam without opening and control beam with circular post opening.

II. EXPERIMENTAL STUDY

2.1 Materials

The mix design for the concrete is carried for M20 grade using OPC 53 grade, local sand and coarse aggregate. The reinforcement in beam consists of 2-12 mm at bottom, 2-10 mm at top and 8 mm stirrups at 150 mm c/c. Ten beams were casted

and cured for 28 days. The post openings of size 100 mm diameter were provided by using drilling machine and one solid beam (i.e. control beam). The CFRP sheets were used for the external strengthening of the beam withcircular opening and these sheets were bonded to the specimen by using epoxy resin.

2.2 Test Specimen

The experimental program includes testing of beams with circular opening having different strengthening techniques. All tested beams had a rectangular cross section of 150mm width and 250mm depth and a effective length of 1800mm. The dimension and location of the opening as shown in figure 1.

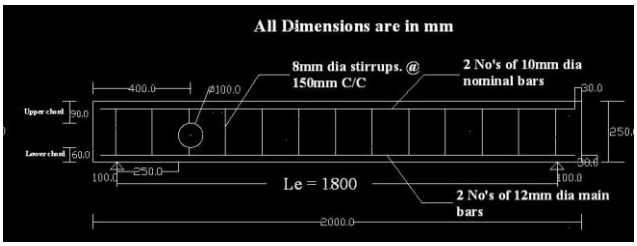

Fig. 1: Dimension of beamwith circular opening

2.3 Strengthening techniques with CFRP sheets

- Strengthening around the opening (wrapping of CFRP sheets around the opening):

Fig. 2: CFRP wrapping around the opening

- Strengthening inside the opening (wrapping of CFRP sheets inside the opening):

Fig. 3: CFRP wrapping inside the opening

- Strengthening around and inside the opening (wrapping of CFRP sheets around and inside the opening):

Fig.4: CFRP wrapping around and inside the opening

2.4 Loading Set Up and Instrumentations

The schematic of the test set up as shown in figure 2. The beams were tested in loading frame (1000 kN capacity) under two point loading. The load was applied incrementally by means of hydraulic jack until beam fails. The deflection at mid span, opening centre and other end without opening were recorded.

Fig.5: Loading Set Up and Instrumentations

III. TEST RESULTS AND DISCUSSIONS

3.1 Test Results

The test results are summarized in Table 1. The table shows initial crack load, ultimate failure load, maximum deflection and modes of failure for all the beams.

Table 1: Test results

Designation on beam	Type of Strengthened	Initial crack load in KN	Ultimate failure load in KN	Increase in load carrying capacity in %	Maximum Deflection	Mode of Failure
B1	Control beam	27.10	79.75	-	10.895	Flexure
B2	Non Strengthened Control Beam (post opening)	19.00	*49.78	-	5.550	Shear
B3	Strengthened around by CFRP Sheets	22.24	67.60	35.79	7.025	Shear
B4	Strengthened inside by CFRP Sheets	19.81	56.26	13.01	6.825	Shear
B5	Strengthened around and	23.86	77.32	55.32	9.925	Flexure

3.2 Discussion

Examining the results presented in the table 1, it is clear that the presence of an opening not only

reduced the load carrying capacity of the beam but also reduce the stiffness of the beam. The reduction in the load carrying capacity of the beam was about 37.58 % due to presence of a 100 mm diameter circular opening within the shear zone. The percentage of increase in load carrying capacity for the beam strengthened with CFRP(B5) sheets around and inside the opening was 55.32% as compared to non-strengthened beam B2 (control beam with circular post opening) and the percentage of increase in load carrying capacity for the beams strengthened with CFRP(B4) inside the opening is 13.01% as compared to non-strengthened beam B2 (control beam with circular post opening).

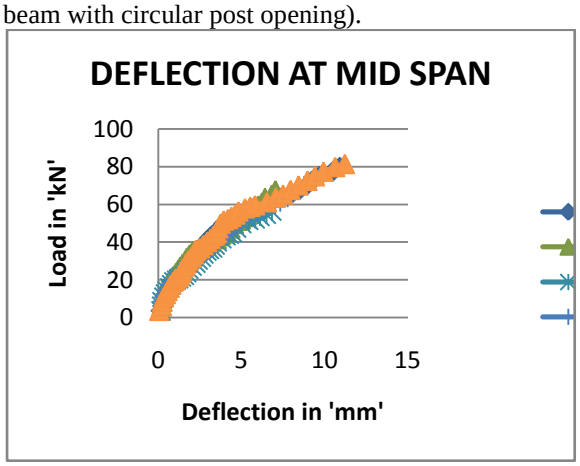

Fig. 6: Load-deflection relationship for all beams at mid span

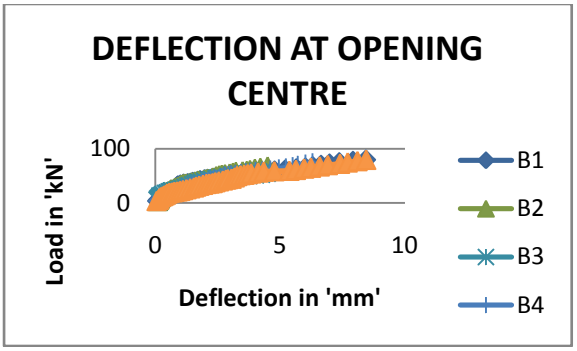

Fig. 7: Load-deflection relationship for all beams at theopening centre

The figure 6 shows load-mid-span deflection relationship for all tested beams. Comparing the deflection for beams B1 and B2 it can be seen that a significance increase in the mid-span deflection for beams B2 than that for beam B1. This is due to the reduction in the stiffness of beam B2 as result of the inclusion of opening. The figure 7 shows load deflection relationship for all tested beams with openings at centre of the opening. It can be seen that external strengthening around and inside the opening significantly increases the beam stiffness at the opening, increase in the load carrying capacity and decrease in deflection as compared to non strengthened beam B2.

IV. CONCLUSIONS

- By an inclusion of circular post opening in the beam the load carrying capacity of the beam decreases by 37.57% as compared to solid beam i.e. control beam due to decrease its stiffness and diagonal cracks were developed due to stress concentration around the opening edges.
- Strengthening of the beam opening with CFRP sheets around the opening is more efficient than strengthening of the beam opening with CFRP sheets inside the opening.
- Strengthening of the beam opening by using CFRP sheets both around and inside the opening increases the load carrying capacity significantly and in case of CFRP sheets percentage of increase in load carrying capacity is 55.32%.
- From the overall study, it can be concluded that the strengthening with CFRP around and inside the opening increases ultimate load carrying capacity and this was best strengthening scheme among all the strengthening process.

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